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THE EFFECT OF OIL CONSUMPTION AND PISTON COOLING ON KNOCK-LIMITED AIRCRAFT-ENGINE PERFORMANCE

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THE EFFECT OF OIL CONSUMPTION AND PISTON COOLING ON KNOCK-LIMITED AIRCRAFT-ENGINE PERFORMANCE

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SUMMARY

Object. - To determine the effects of oil introduced into the combustion chamber and of oil-spray piston cooling on the knock-limited performance of aircraft engines.

Scope. - Tests of knock-limited performance were conducted on a CFR engine in which 2.5 percent by weight of two different oils and kerosene were mixed, in turn, with S-2 reference fuel.

Tests on an Allison V-1710 cylinder were also conducted in which 0 to 6.1 pounds of SAE 50 oil per hour were injected directly into the combustion chamber, and the knock-limited performance of aviation gasoline AN-VV-F-781, amendment-5, (125 performance number) was determined. The effect of oil cooling of the piston was also investigated.

Summary of results. - The results are summarized in tables 1 and 2.

TABLE 1. - APPROXIMATE PERCENTAGE DECREASE IN KNOCK-LIMITED POWER FOR EACH INCREASE IN OIL CONSUMPTION OF 0.01 POUND PER HORSEPOWER-HOUR

Oil introduced into combustion chamber	Fuel	Decrease in knock-limited power (percent)	
		Fuel-air ratio	
		0.075	0.10
CFR engine (oil premixed with fuel)[a]			
SAE 60	S-2	16	8
SAE 10W	S-2	13	5.5
Kerosene	S-2	14	5.5
Allison V-1710 cylinder (oil injected into combustion chamber)[b]			
SAE 50	AN-VV-F-781, Amendment-5, (125 performance number)	4	2

[a]Indicated basis.
[b]Brake basis.

TABLE 2. - APPROXIMATE PERCENTAGE DECREASE IN KNOCK-LIMITED POWER FOR EACH INCREASE IN OIL CONSUMPTION OF 1 PERCENT OF THE FUEL CONSUMPTION

Oil introduced into combustion chamber	Fuel	Decrease in knock-limited power (percent)	
		Fuel-air ratio	
		0.075	0.10
CFR engine (oil premixed with fuel)			
SAE 60	S-2	7	5
SAE 10W	S-2	6	4
Kerosene	S-2	6	4
Allison V-1710 cylinder (oil injected into combustion chamber)			
SAE 50	AN-VV-F-781, Amendment-5, (125 performance number)	2	1.5

INTRODUCTION

The effect of oil consumption on the knock-limited performance of an aircraft engine is important from the considerations of flight operation. Under service conditions the engines may operate close to or at the predetermined knock limit. Any change, such as increased oil consumption, that materially lowers this knock limit can cause damage to the engine without warning to the pilot.

In the knock testing of fuels it is commonly known that variations in oil consumption cause variations in knock rating. From tests of an unsupercharged CFR engine, Stacey (reference 1) concluded that changes in knock rating of as much as 1 octane number may be attributed to different rates of oil consumption. Similar work was conducted by King and Moss (references 2 and 3).

Data are reported herein that show the effect of oil consumption on the knock-limited performance of a supercharged high-speed CFR engine. Two different oils and kerosene were used. These tests were made at the Langley Memorial Aeronautical Laboratory, Langley Field, Va., in 1942.

Information concerning the effect of SAE 50 oil consumption on the knock-limited power of an Allison V-1710 cylinder was obtained at the Aircraft Engine Research Laboratory, Cleveland, Ohio, in January and February 1943. The results of these tests are also included.

In the Allison setup, information was lacking on the proper quantity of oil to spray on the under side of the piston and on the lower cylinder barrel to simulate piston-cooling conditions in multicylinder engines. Because this cooling factor was unknown, it was necessary to determine by testing whether or not the quantity of cooling-oil spray to the piston and lower cylinder barrel had a critical effect on the knock-limited power of the Allison engine.

Inasmuch as variations in quantity of oil spray resulted in variations in the rate of oil consumption as well as in the cooling, it was necessary, in order to separate variables, to make further tests to determine the knock sensitivity of this cylinder to oil consumption.

APPARATUS AND TEST PROCEDURE

<u>CFR engine</u>. - A high-speed CFR engine, coupled with a cradle-mounted dynamometer, was used in the test program. A detailed description of the apparatus can be found in reference 4. In these

tests, 2.5 percent by weight of kerosene and two oils - SAE 60 and SAE 10W - were premixed with S-2 reference fuel. Knock tests were run with each of the mixtures and with clear S-2 reference fuel. A cathode-ray oscilloscope and a magnetostriction pickup unit were used to detect knock.

In order to get an accurate comparison of the performance of the S-2 fuel containing oil and the clear S-2 fuel, the data on each blend and on the clear S-2 fuel with which it was compared were taken on the same day.

Allison V-1710 cylinder. - An Allison V-1710 single cylinder was mounted on a CUE crankcase, coupled with a cradle-mounted eddy-current dynamometer. Oil from the engine lubrication system was injected directly into the combustion chamber at a constant rate and knock data were taken at various fuel-air ratios using AN-VV-F-781, Amendment-5, fuel. Data were obtained with various rates of oil injection into the combustion chamber and with different amounts of oil spray to the under side of the piston. Knock was detected by means of an oscilloscope and a piezoelectric pickup.

Injection into the cylinder was accomplished by an injection pump and a single-orifice spring-loaded valve that injected oil at a pressure of approximately 1000 pounds per square inch at 50° B.B.C. on the intake stroke. A solid stream rather than a fine mist was injected and was directed at the cylinder wall, thereby more closely simulating flow past the piston and the piston rings than by admixing the oil with the gasoline.

The rate of oil consumption was determined at regular intervals by weight measurements of the oil in the engine lubricating system. The loss in oil from this system included the oil injected into the combustion chamber and the oil that passed by the piston rings into the combustion chamber. The average rate of loss of oil from the lubrication system during a test was taken as the rate of oil consumption.

Piston cooling was accomplished by use of a rifle-drilled connecting rod with two jets for spray of oil on the under side of the piston and an auxiliary spray nozzle located in the crankcase and directed at the under side of the piston. The auxiliary spray was used to provide a controllable rate of oil spray to the under side of the piston. The flow was regulated by a valve in the supply line. The quantity of oil flowing from jets in the connecting rod remained constant throughout the tests at about 3 pounds per minute.

The flow through the auxiliary nozzle was kept at 7.5 pounds per minute, which made a total of 10.5 pounds per minute when this nozzle was used.

Test conditions. - Operating conditions prevailing throughout the tests on the CFR engine and the Allison V-1710 cylinder were as follows:

	CFR	Allison V-1710
Engine speed, rpm	2000	2500
Compression ratio	7.0	6.65
Spark advance, degrees B.T.C.		
Inlet	34±0.5	28
Exhaust		34
Inlet-air temperature, °F	200	200
Inlet-coolant temperature, °F	317 to 326	---
Outlet-coolant temperature, °F	---	250
Inlet-oil temperature, °F	---	185

RESULTS AND DISCUSSION

The effect of the two oils and the kerosene examined in the CFR engine on the allowable knock limit of S-2 fuel is shown in figures 1 and 2. The SAE 60 oil produced the greatest decrease in knock-limited power in the rich region when mixed with S-2 fuel. In figure 1 it may be seen that 2.5 percent SAE 60 oil in S-2 fuel permitted 82 percent of the knock-limited power with clear S-2 fuel at a fuel-air ratio of 0.075. At a fuel-air ratio of 0.10, the knock-limited power was 88 percent of the knock-limited power with clear S-2 fuel. Linear interpolation of the foregoing values for SAE 60 oil indicates that the knock-limited power is decreased 7 and 5 percent for lean and rich mixtures, respectively, for each increase in oil consumption of 1 percent of the fuel consumption.

Figures 3 to 6 present data for the Allison V-1710 cylinder. Figure 3 shows the effect of injecting various quantities of SAE 50 oil into the combustion chamber when the engine was operating with and without the auxiliary oil spray impinging on the under side of the piston.

The results shown in figure 3 are cross-plotted in figures 4 and 5 and indicate that the knock-limited brake mean effective pressure varies linearly with the amount of oil injected with the fuel. The points in figures 4 and 5 show the accuracy of the data and are

not test points. A change in brake specific oil consumption (bsoc) from 0.01 to 0.04 pound per brake horsepower-hour was found to effect a reduction in the knock-limited brake mean effective pressure of approximately 11 percent at a fuel-air ratio of 0.075 (fig. 4). These results also show that the injection of oil into the combustion chamber causes a somewhat greater percentage reduction in knock-limited brake mean effective pressure at lean mixtures than at rich mixtures. Presence of the auxiliary oil spray directed to the under side of the piston raised the knock-limited brake mean effective pressure about 5 percent at a fuel-air ratio of 0.075 and a brake specific oil consumption of less than 0.02 pound per brake horsepower-hour.

Table 3 summarizes the effect on the oil consumption of oil injection into the combustion chamber and of oil spray onto the under side of the piston.

TABLE 3. - EFFECT ON THE OIL CONSUMPTION OF OIL INJECTION INTO THE COMBUSTION CHAMBER AND OIL SPRAY ONTO THE UNDER SIDE OF THE PISTON

Oil spray to piston and lower cylinder (lb/min)	Oil injected into combustion chamber (lb/hr)	Total oil consumption (lb/hr)	Oil consumed in passing by piston rings (lb/hr)
10.5	0.0	1.26	1.26
10.5	4.1	5.04	.94
10.5	6.1	6.25	.15
3.0	.0	.83	.83
3.0	2.4	2.78	.37
3.0	6.1	6.10	.00

Figure 6 furnishes information on the heat balance in this engine as affected by the oil spray on the under side of the piston and by the fuel-air ratio. The data show that the oil spray to the under side of the piston more than doubled the total heat rejection to the oil.

The data included in this report show only the effects of oil consumption on the knock-limited performance of fuel and do not show the effects of oil consumption on engine deposit and cylinder wear. Good cylinder lubrication cannot be had unless a certain amount of oil passes by the rings into the combustion chamber. Continued

running with a high rate of oil consumption forms deposits of carbon on the piston and on the combustion-chamber walls, which further reduce the knock-limited performance.

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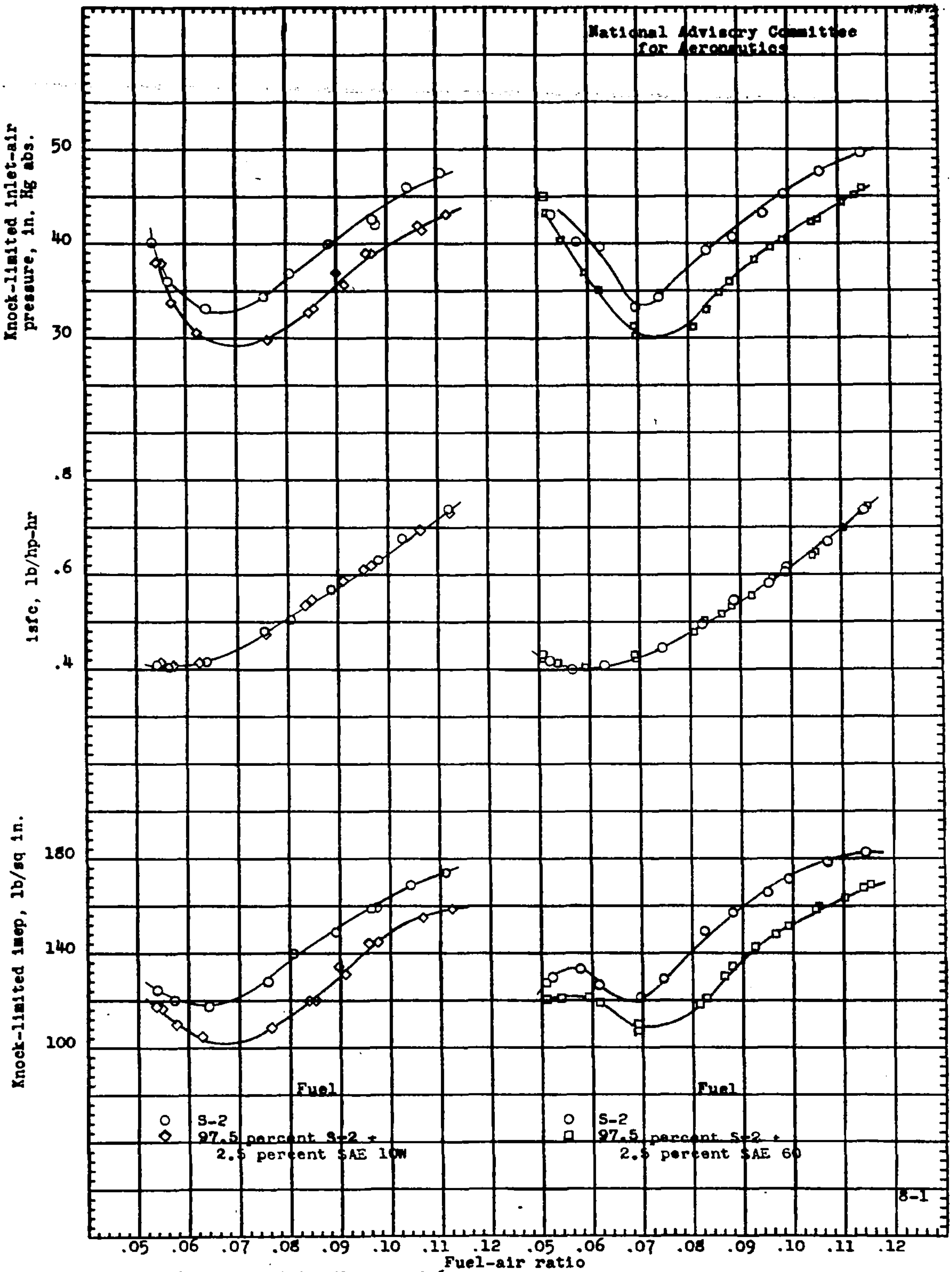

Figure 1. - Effect of SAE 10W and SAE 60 oils on the knock-limited performance of S-2 reference fuel in a CFR engine. Compression ratio, 7.0; spark advance, 34° B.T.C.; inlet-coolant temperature, 317° F; inlet-air temperature, 200° F; engine speed, 2000 rpm.

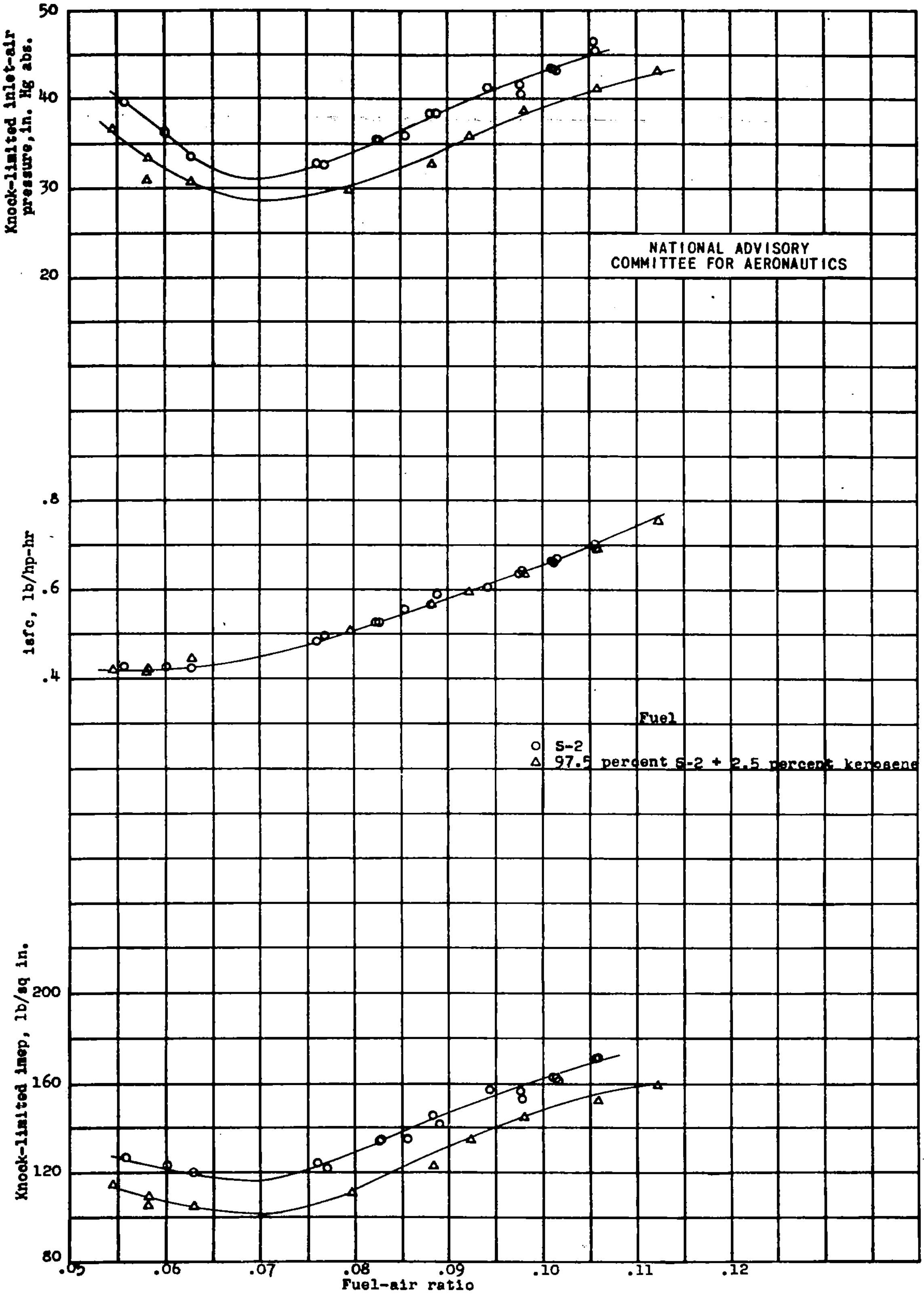

Figure 2. - Effect of kerosene on the knock-limited performance of S-2 reference fuel in a CFR engine. Compression ratio, 7.0; spark advance, 34° B.T.C.; inlet-coolant temperature, 323° to 326° F; inlet-air temperature, 200° F; engine speed, 2000 rpm.

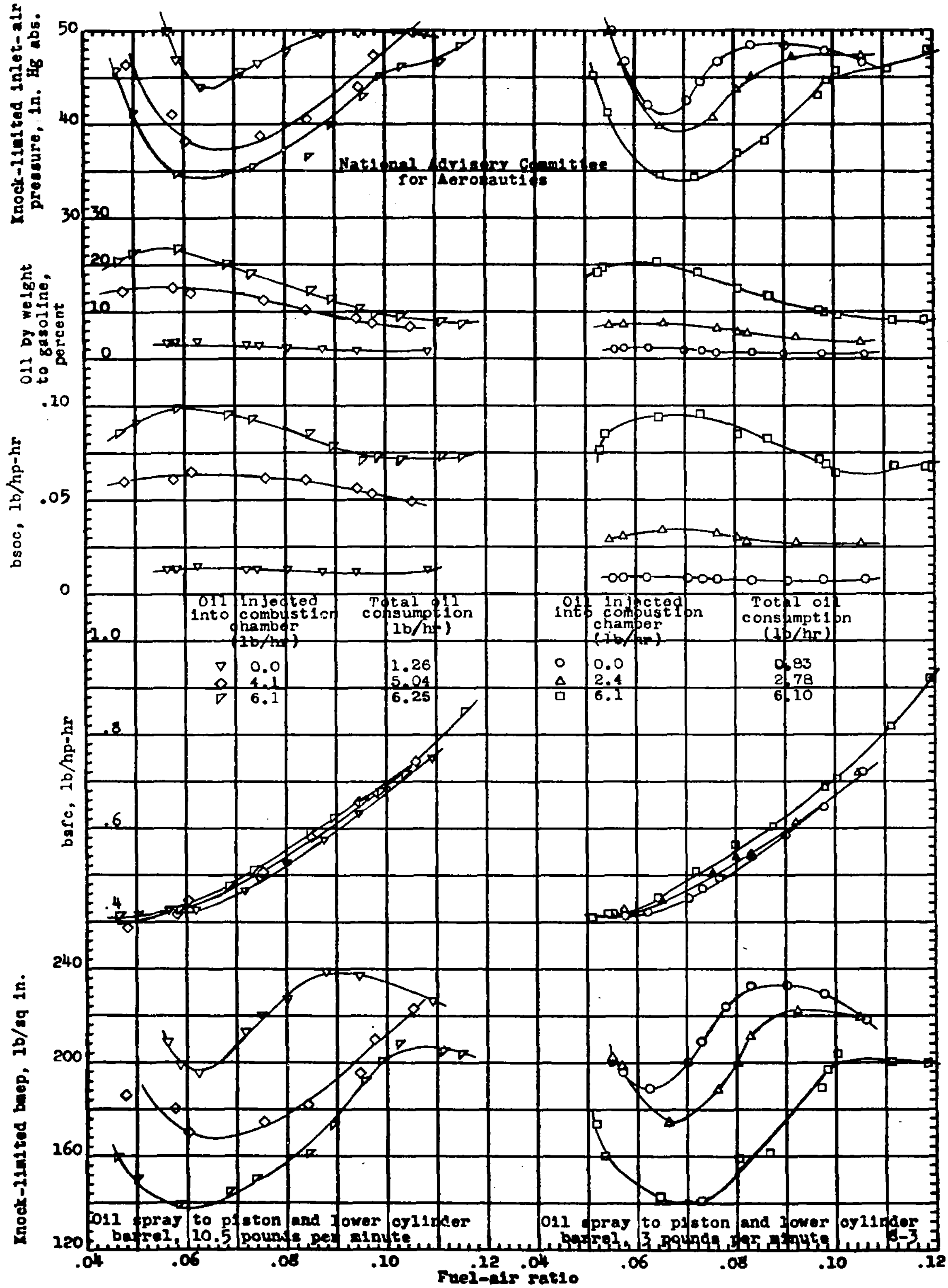

Figure 3. - Effect of introducing SAE 50 oil into the combustion chamber of an Allison V-1710 cylinder on the knock-limited performance. Compression ratio, 6.65; spark advance: inlet, 28° B.T.C.; exhaust 34° B.T.C.; outlet-coolant temperature, 250° F; inlet-oil temperature, 185° F; inlet-air temperature, 200° F; engine speed, 2500 rpm; fuel, 125-performance-number aviation gasoline.

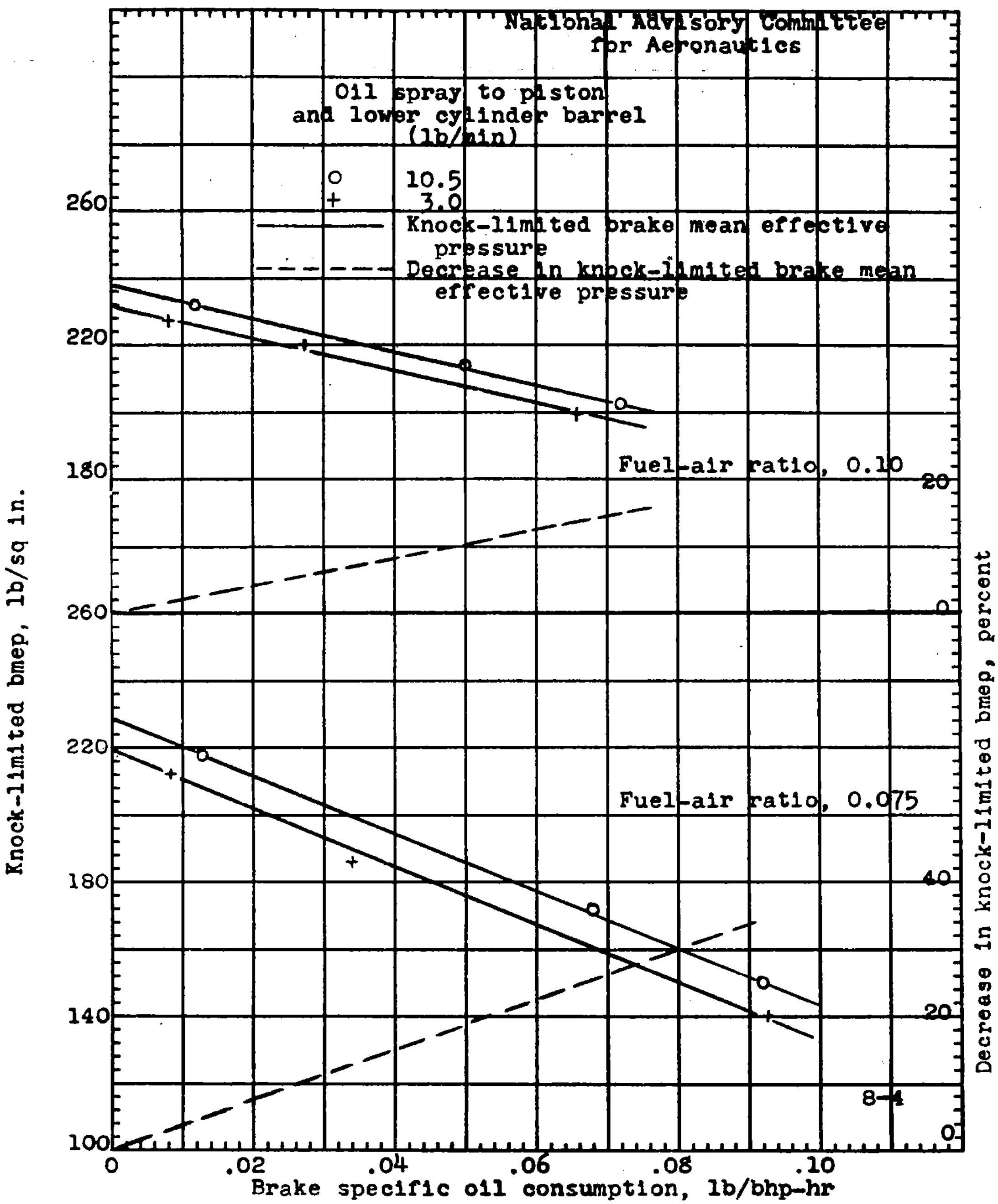

Figure 4.- Effect of brake specific oil consumption on the knock-limited performance in an Allison V-1710 cylinder. SAE 50 oil; compression ratio, 6.65; spark advance: inlet, 28° B.T.C., exhaust, 34° B.T.C.; outlet-coolant temperature, 250° F; inlet-oil temperature, 185° F; inlet-air temperature, 200° F; engine speed, 2500 rpm; fuel, 125-performance-number aviation gasoline.

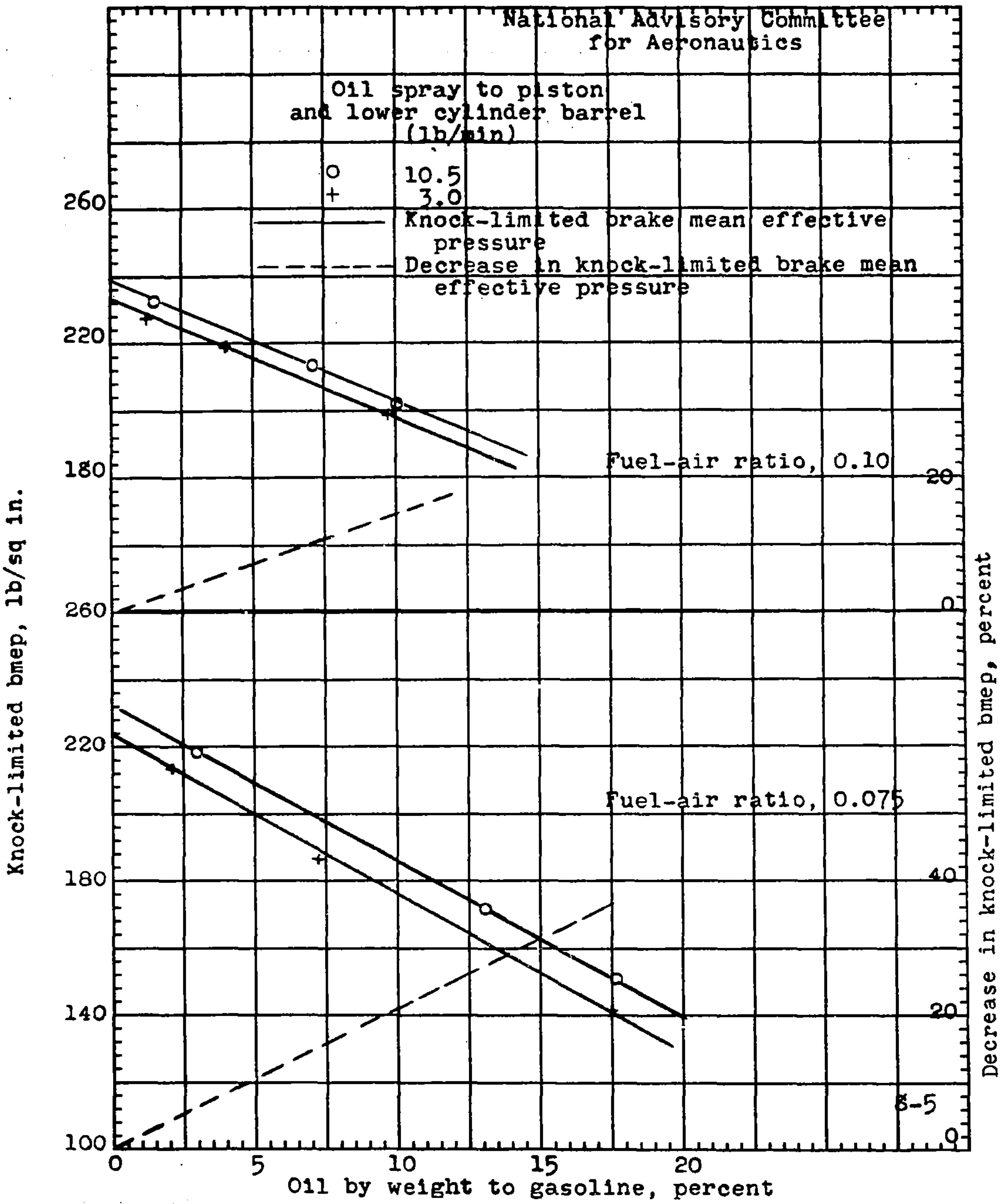

Figure 5. - Effect of weight percentage of oil to gasoline on the knock-limited performance in an Allison V-1710 cylinder. SAE 50 oil; compression ratio, 6.65; spark advance: inlet, 28° B.T.C.; exhaust, 34° B.T.C.; outlet-coolant temperature, 250° F; inlet-oil temperature, 185° F; inlet-air temperature, 200° F; engine speed, 2500 rpm; fuel, 125-performance-number aviation gasoline.

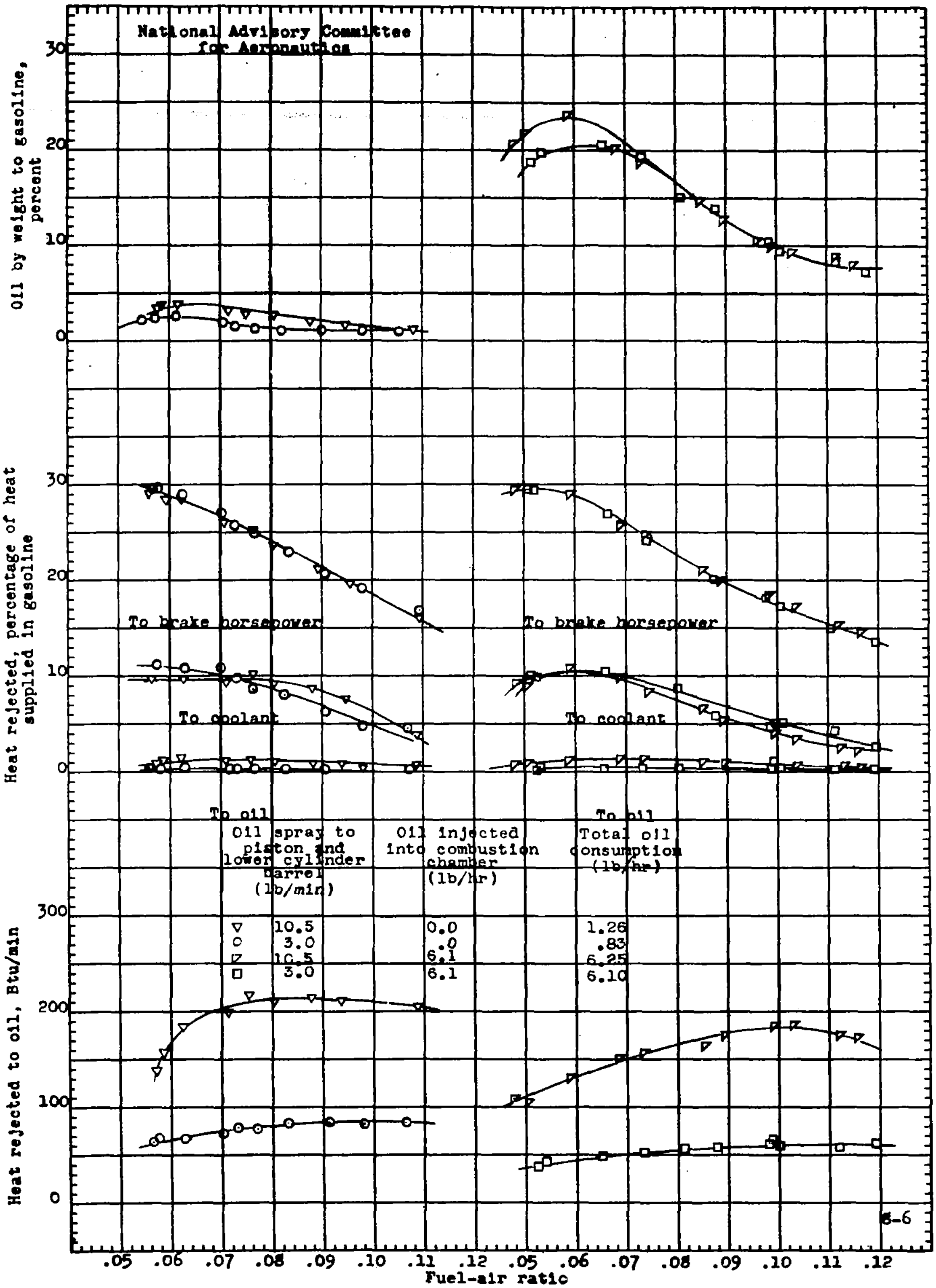

Figure 6. - Effect of an oil spray to the under side of the piston and to the lower cylinder barrel of an Allison V-1710 cylinder on the heat rejected to the oil. Compression ratio, 6.65; spark advance, inlet 28° B.T.C., exhaust 34° B.T.C.; outlet-coolant temperature, 250° F; inlet-air temperature, 200° F; engine speed, 2500 rpm; fuel, 125 performance-number aviation gasoline.